Exxon Background Series

WORLD ENERGY OUTLOOK

December 1979

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A background paper prepared by the Public Affairs Department of Exxon Corporation in cooperation with other Exxon departments and affiliates.

For many years Exxon Corporation, on the basis of information provided by its affiliates around the world, has prepared energy projections as part of its planning effort. Recently these energy outlooks have been made public in the thought that they would be of interest to a general audience and in the hope that they would contribute to informed decisions on policy issues relating to energy.

Exxon's current World Energy Outlook[1], prepared over a period of six months ending in October 1979, projects demand and supply of energy[2] to the year 2000. It includes a world economic outlook as well as supply and demand projections for oil and other energy forms.

This Outlook should not be viewed as a prediction, but as a series of projections based on general economic assessments, energy cost assumptions, environmental and public constraints affecting energy, and an area-by-area evaluation of available energy resources. The Outlook does not try to encompass all possible outcomes of the political, economic, social and technological developments which could occur. Recurrent periods of political unrest, business cycles, and energy supply disruptions have been recognized in framing the projections. But no provision has been made for major political upheavals, deep economic depression, or substantial new barriers to world trade and investment.

The purchase prices of crude oil in the Middle East, projected when Arab light crude was priced at $18 per barrel, are assumed to rise in real terms to approximately $25 per barrel in 1985 and $28 per barrel in 1990, all in December 1979 dollars. This is somewhat above the levels assumed in the U. S. Department of Energy's Energy Information Administration's Case B published in the summer of 1979, but below those assumed by the U.S. Senate Finance Committee in its recent projections of the effects of various tax proposals. OPEC price increases, announced in December 1979, were in fact significantly greater than those assumed in this Outlook.

[1] Net energy imports from the U.S.S.R., Eastern Europe and the People's Republic of China are included in the Outlook, but their internal supply and demand balances are not.

[2] The term "energy" refers throughout to energy obtained from commercial sources. Especially in the less developed countries, a significant portion of total energy consumption may come from non-commercial sources such as animal, wood and crop wastes.

Due to rounding some numbers in charts may not total correctly.

The world has begun a transition toward increased use of energy sources other than conventional oil. While this transition will probably lead ultimately to greater use of renewable energy forms such as solar and fusion, these are not likely to make large volumetric contributions to total energy supply for several decades. In the meantime coal, nuclear and fossil-based synthetics will play an increasing role.

For most consumers, energy in the future will cost a good deal more than it has historically. Even the discovery and development of remaining conventional oil reserves will incur much higher costs. Compared to the past, future oil discoveries are likely to be smaller, at greater depths, in more physically hostile environments, and at locations more remote from markets.

Both the magnitude of investments required and the lead time between the decision to invest and the start of production are increasing in new energy supply projects. Thus, future energy supply depends upon actions by investors and by governments far in advance of the need for supply. Today's governmental and commercial decisions will affect the availability of energy supplies many years hence.

This Outlook is based on an assessment of world economic activity which indicates that the rate of world economic growth will probably be about two-thirds the 1965 to 1973 level. The results of the Outlook may be summarized as follows:

- Energy demand may grow only half as rapidly as in the 1965 to 1973 period. Nonetheless, by 2000 the world will probably be consuming two-thirds more energy than at present.

- Oil demand is projected to grow at an annual rate of less than 1 percent, compared to over 7 percent from 1965 to 1973. The amount of oil used in industrial nations is expected to remain essentially constant, but its use will increase in developing countries.

- Conventional oil production will probably plateau around the turn of the century. The transition to greater reliance on other energy forms will be well under way by that time and it will be characterized by:

  Substantial increases in the use of coal and nuclear energy which can be achieved only by the resolution of political, technological and environmental issues.

  Development of major synthetic oil and gas production by the 1990s. Large-scale synthetics production will be concentrated in a few areas containing the necessary coal, oil shale and heavy oil reserves. It is assumed that this will take place principally in North America. Massive investments as well as an early resolution of environmental, infrastructure and social issues will be required to facilitate production.

  Greater use will be made of solar energy in its various forms, but a significant contribution to total energy supply from this source is more likely to occur after the turn of the century.

- The transition to greater reliance on energy forms other than conventional oil will be eased by a reduction in the energy intensity of overall economic activity. Less energy will be consumed per unit of output as a result of conservation, new technology and investments to increase energy efficiency, as well as further shifts in the mix of economic output to less energy-intensive activities.

The projections set forth here were prepared in a period of particularly rapid change in perceptions of world energy supply and demand and in oil prices. Factors that shaped the projections continue to change. For example, the extent of price changes by the Organization of Petroleum Exporting Countries (OPEC) in late 1979 was not anticipated in the Outlook. However, the data shown in the charts are broadly representative of possible future trends, if assumptions about future public policies are correct. If the price projections in this Outlook continue to be exceeded, the trend towards reliance on energy supplies other than conventional oil could be accelerated.

ECONOMIC GROWTH PROSPECTS

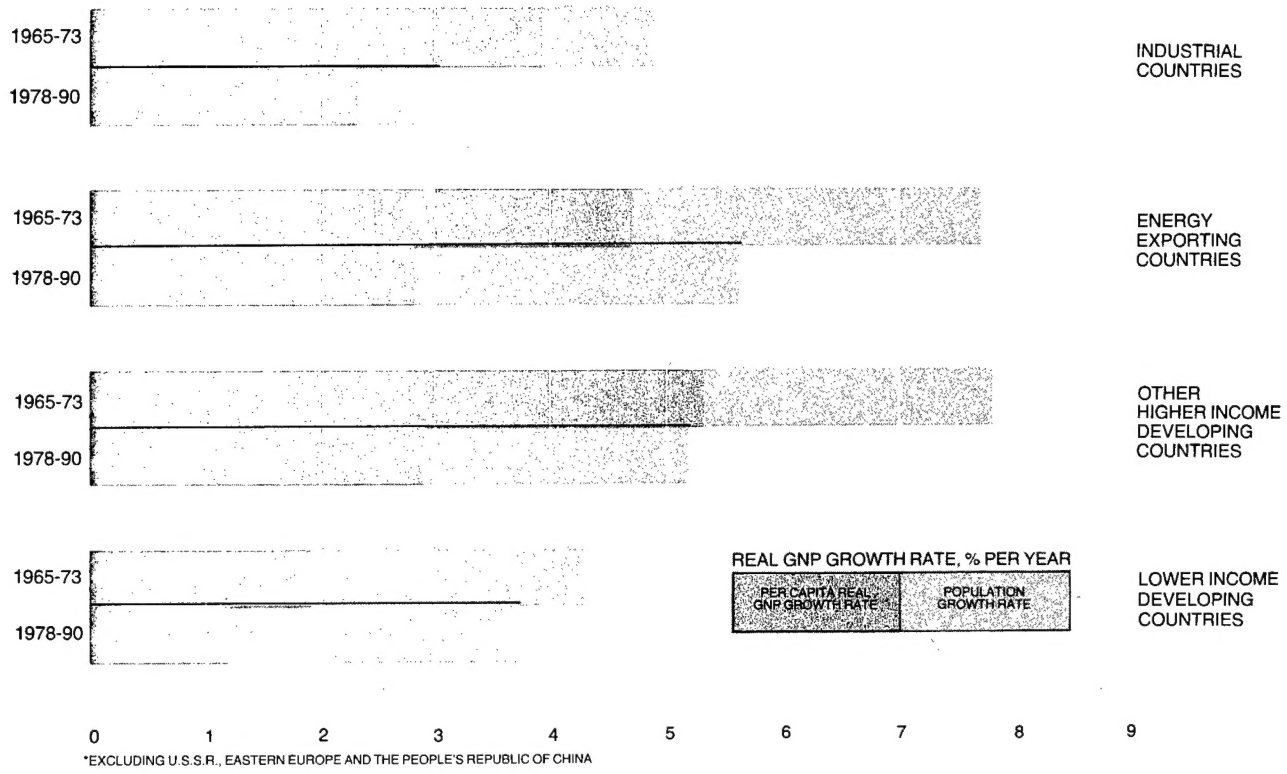
4 The projection of world economic growth represented on this chart is basic to the energy outlook. Adjusted for inflation, the average growth in world gross national product (GNP) is projected to be about 3½ percent per year from 1978 to 2000. This contrasts with a 5 percent per year growth rate in the 1965 to 1973 period and is only slightly above the 3 percent rate experienced since 1973. It reflects both a slower rate of population increase than in the past and lower productivity gains.

The chart shows the world divided into four groups of countries through the initial part of the outlook period. The industrial countries–the United States, Canada, Japan, and those in Western Europe–grew at about 5 percent per year from 1965 to 1973. This is slightly above the 4½ percent per year rate for the low income developing countries, but well below the nearly 8 percent per year rate for both the energy exporters and the other higher income developing countries.

For the outlook period to 1990, all country groupings are expected to grow more slowly than in the 1965 to 1973 period. The industrial group averages 3 percent per year. The higher income developing countries and energy exporting countries are in the 5 to 6 percent per year range. In the lower income group of developing countries, growth of about 3½ to 4 percent per year will probably continue.

The left hand portions of the bars show growth in real GNP per capita. For the first three country groupings annual increases in real per capita income for the future period average 2½ to 3 percent per year. The lower income developing countries are projected to have increases of 1 to 1½ percent per year.

WORLD* ECONOMIC GROWTH RATES



*EXCLUDING U.S.S.R., EASTERN EUROPE AND THE PEOPLE'S REPUBLIC OF CHINA

WORLD ENERGY DEMAND

6 This chart displays projected total demand for energy over the next two decades. Demand is expected to grow at less than one-half the 1965 to 1973 rate—that is, at about 2½ percent per year compared with 5½ percent per year in the earlier period. The lower rate reflects both slower economic growth and less energy intensity. Nonetheless, world energy demand is projected to reach nearly 130 million barrels per day oil equivalent by 1990 and to exceed 160 million barrels per day by 2000. This represents an increase over 1978 levels of about one-third by 1990 and two-thirds by 2000.

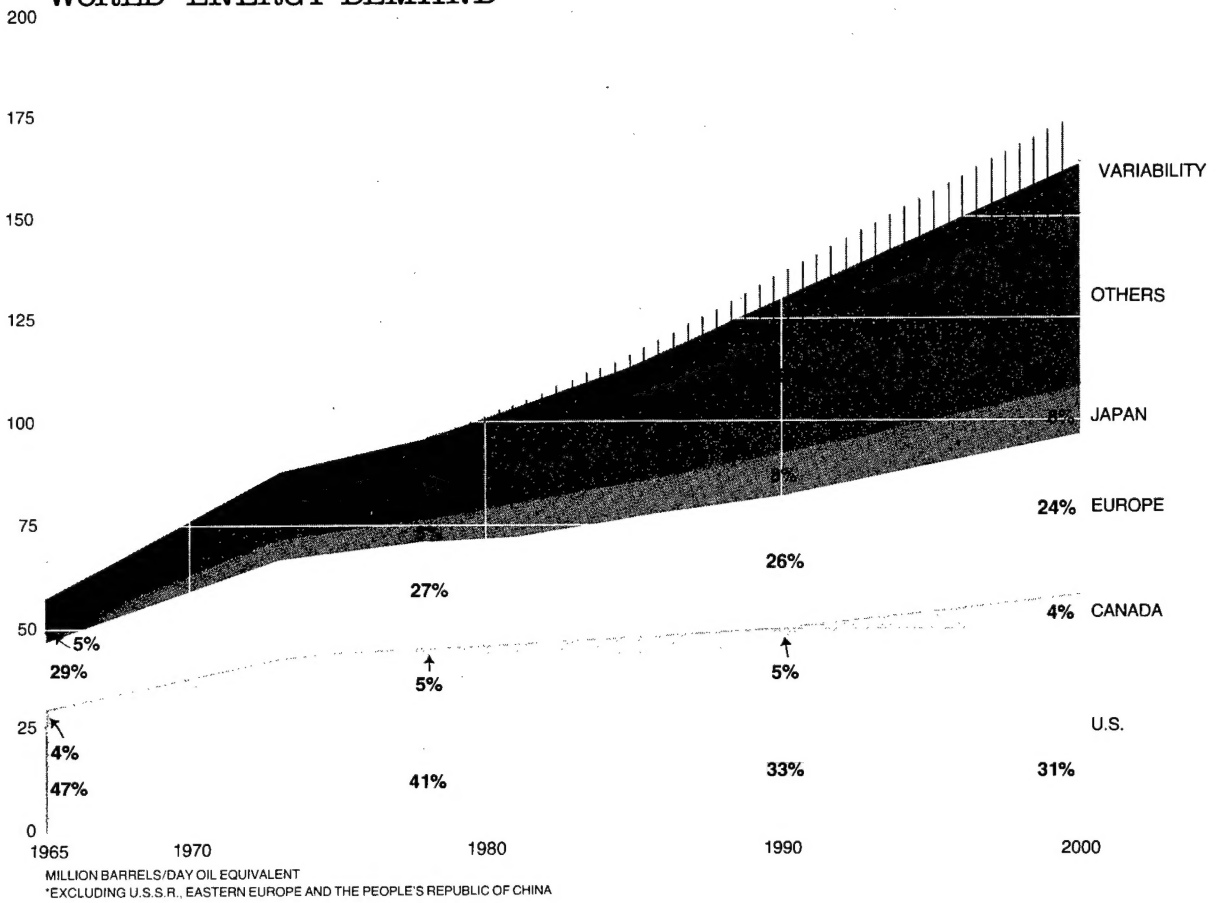
Energy demand may vary significantly from this projection if economic growth rates turn out to be different than projected, or if the projected improvements in energy efficiency prove incorrect. These factors can be affected by government energy policies and the rate of technological advancement. For example, if economic growth rates were to vary by ½ percent per year from those projected here, energy demand could vary by about plus or minus 6 million barrels per day oil equivalent in 1990 and by 13 million barrels per day in 2000. This is indicated by the hatched area on the chart.

In this Outlook the United States' share of total energy demand declines from 41 percent currently to less than one-third by 2000. The share of European countries declines slightly, while that of Japan remains unchanged. The share of "Others," principally developing countries, rises from 19 percent of total energy demand in 1978 to 33 percent by 2000. Within this group, the share of energy demand accounted for by energy exporting countries rises from 8 percent to 16 percent. Energy importing developing countries may be expected to increase their share of world energy use from 11 percent to 17 percent by 2000. The following table summarizes projected energy demand growth rates for the areas shown on the chart.

ENERGY DEMAND GROWTH, PERCENT PER YEAR

	1965-1973	1973-1978	1978-1990	1990-2000
United States	4.3	1.0	0.8	1.6
Canada	5.9	2.8	2.4	1.4
Europe	5.1	1.0	2.0	1.7
Japan	11.4	0.8	2.9	1.9
Others	6.9	4.8	5.8	4.0
Total	5.5	1.7	2.6	2.4

WORLD* ENERGY DEMAND



MILLION BARRELS/DAY OIL EQUIVALENT

*EXCLUDING U.S.S.R., EASTERN EUROPE AND THE PEOPLE'S REPUBLIC OF CHINA

The major industrialized nations have been reducing the energy intensity of their economies since the early 1970s. That is, they are consuming less energy per unit of economic output than previously. Reductions in energy intensity can occur because of energy efficiency improvements (performing the same task with less energy), energy conservation measures (doing with less) and changes in the mix of production in the economy (more services and less heavy industry). All of these factors have been considered in this Outlook.

Significant reductions in energy intensity have become increasingly evident since the sharp increases in oil prices starting in the early 1970s. In the United States, about 8½ barrels of oil equivalent were consumed per $1000 of GNP (in 1975 dollars) in the 1960s. By 1978, 6 percent less energy was required per unit of GNP than the pre-1970 average. This was equivalent to a demand reduction in the range of 2 to 2½ million barrels per day oil equivalent. In the industrial world outside the United States, the aggregate pre-1970 energy/GNP ratio was 5¼ barrels of oil equivalent per unit of economic output. By 1978, the ratio was 3 percent lower, which equates to a demand reduction in the 1 to 1½ million barrels per day range.

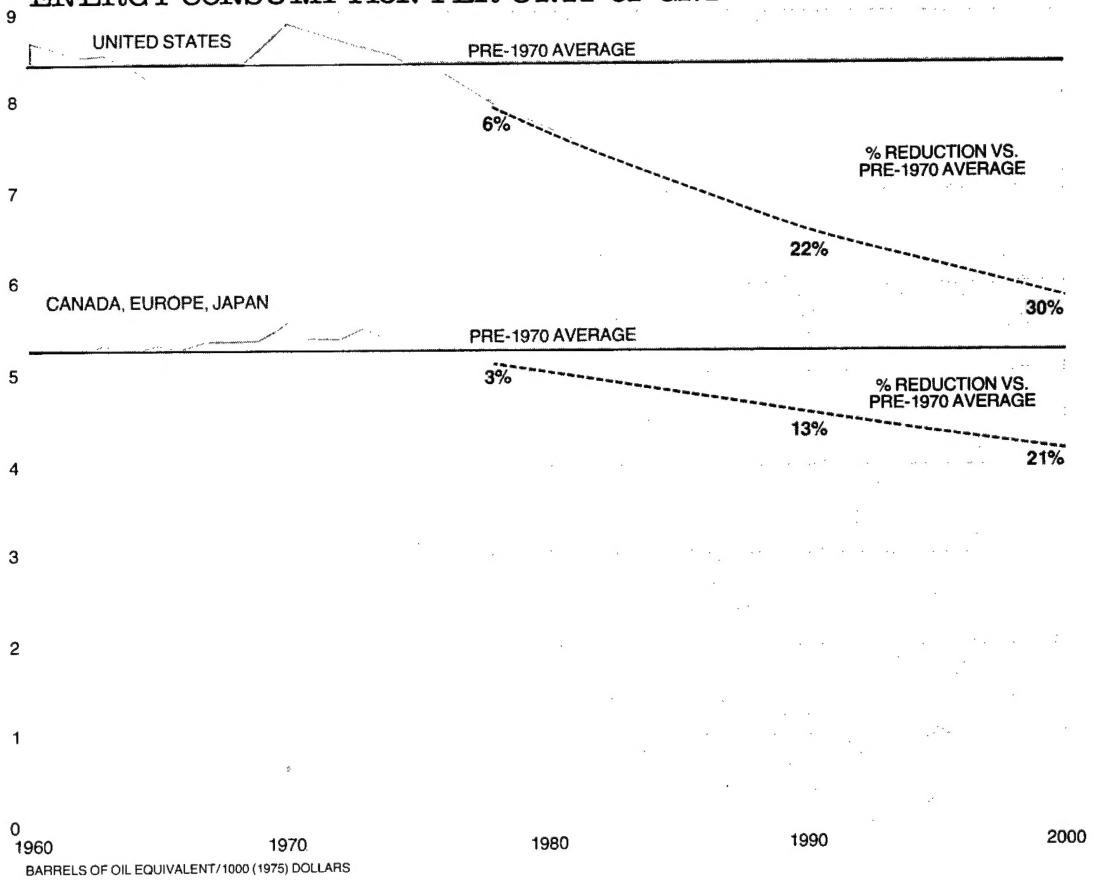
Relationships such as the energy/GNP ratio are useful primarily in assessing trends within a given country or region. Several of the factors which cause one area's energy/GNP ratio to differ from another's are relatively unchanging. They include climate, population density, geography, age and mix of capital stock, and life styles.

Further reductions in energy intensity are expected to occur. Thus far, reductions have occurred in the residential/commercial sector as a result both of conservation and increased efficiency—for example, adjustments in thermostat settings and addition of insulation, respectively. The industrial sector has shown steady improvements worldwide, while greater efficiency in the transportation sector will continue especially in the United States and Canada. The continuation of the downward trend in energy intensity projected for the industrial world in the 1990s assumes that technological developments not now known will be forthcoming in response to higher energy costs to support further increases in the energy efficiency of new capital goods.

The energy/GNP ratio projections shown on the chart were derived from the economic and energy outlooks for the individual areas, as opposed to being assumed as determinants for the Outlook. By 1990, the projection for the United States indicates a 22 percent reduction in energy consumed per unit of GNP compared to pre-1970 trends, increasing to 30 percent by 2000. Expressed in terms of lower levels of total energy demand, the reductions are equivalent to about 12½ million barrels per day in 1990, rising to more than 20 million barrels per day in 2000. U.S. energy consumption per $1000 (1975 dollars) of GNP by 2000 is projected to be slightly under 6 barrels of oil equivalent. This is about 2 barrels of oil equivalent per unit of GNP less than was required in 1978.

For the industrial world outside the United States, the combined energy/GNP ratio is also projected to continue to decline, though at a somewhat more moderate pace than in the United States. For 1990, the Outlook indicates a 13 percent reduction in energy consumption per unit of GNP, equivalent to about 7 million barrels per day. A further reduction to 21 percent is projected by 2000, which amounts to about 16 million barrels per day lower demand. For this part of the industrial world, the energy requirement per unit of GNP is projected to decline to just over 4 barrels of oil equivalent in 2000, about 1 barrel per unit less than the 1978 requirement.

ENERGY CONSUMPTION PER UNIT OF GNP



A significant shift towards the utilization of energy sources other than oil has been taking place. In the 1965 to 1973 period, production of oil and gas was growing 7 to 8 percent per year (see table below). In the 1990s, the growth rate for these fuels is projected to be less than 1 percent per year. All other sources of energy have expected growth rates above that for total energy.

ENERGY SUPPLY GROWTH, PERCENT PER YEAR

	1965-1973	1973-1978	1978-1990	1990-2000
Oil	7.7	0.5	1.1	0.3
Gas	6.9	1.1	2.7	1.0
Synthetics	–	15.4	25.7	14.0
Coal	(0.5)	1.4	3.7	4.1
Nuclear	27.2	23.9	11.3	5.9
Hydro & Other	3.8	4.4	3.4	3.9
Total	5.5	1.7	2.6	2.4

The share of energy supply from conventional oil is projected to decline from 54 percent in 1978 to about 37 percent by 2000. However, as the chart shows, oil will continue to supply significantly more of the world's energy needs than any other fuel.

Natural gas met 18 percent of world energy supply in 1978. Its share is projected to decline to 16 percent by 2000 despite a 50 percent increase in production. Reserves to support this growth are believed to be available. However, most are in remote areas, and the facilities required to move the gas to market are expensive and entail considerable commercial risk. Nevertheless, between now and 1990 liquefied natural gas (LNG) imports into Europe and Japan are expected to increase fivefold. Since international contracts must be negotiated, and ships and complex facilities built, the possibility of variation is significant. Lead times for projects to import LNG currently average seven to ten years. Problems related to gas delivery, rather than the resource base, are likely to limit gas use over this period. Unconventional gas sources, such as tight sands, Devonian shale and geo-pressurized zones, will supply only small volumes by 2000, mainly in the United States.

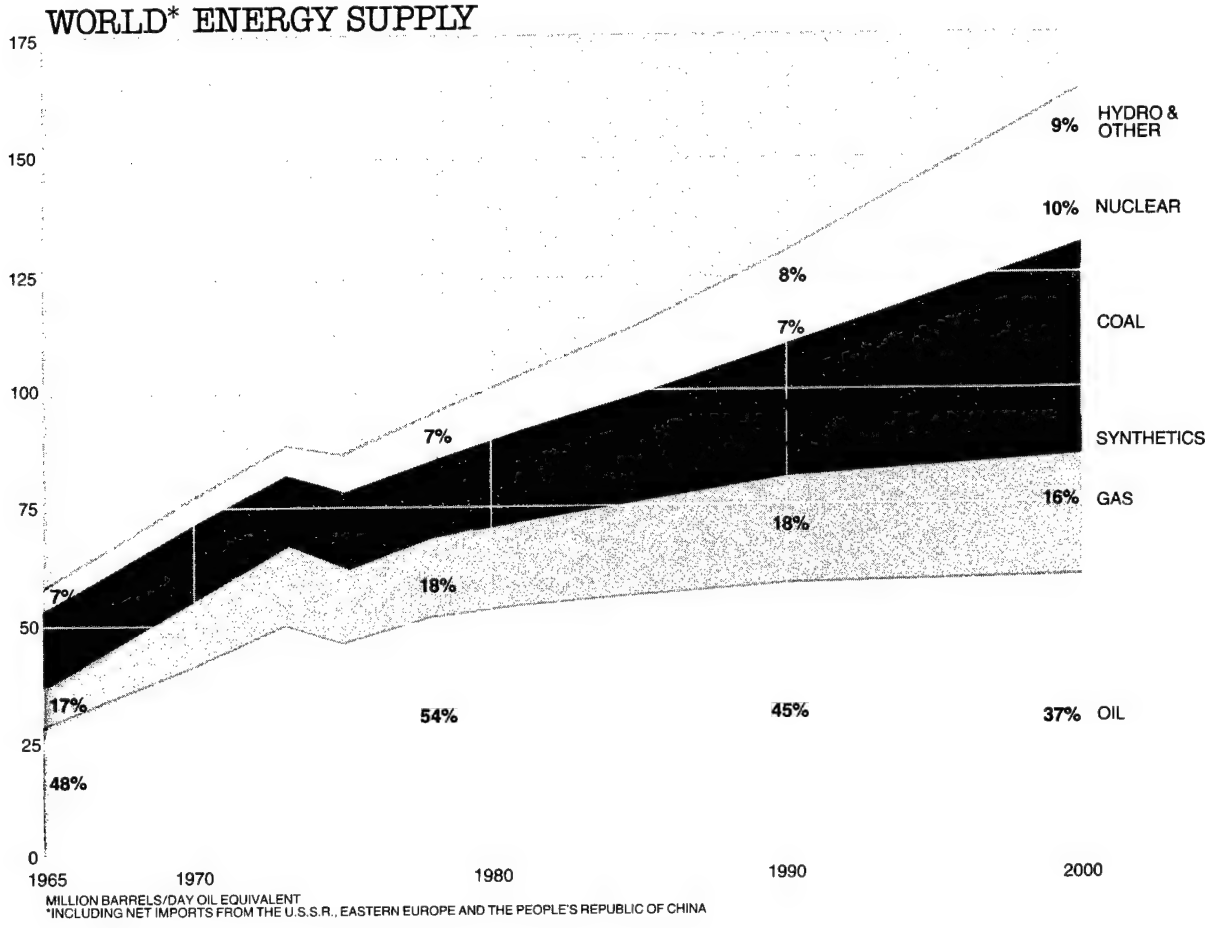
Synthetics are expected to become significant in meeting the world's energy needs in the early 1990s, and they are projected to contribute 4 percent of world energy supply by 2000.

Coal is projected to break out of its pattern of low growth. Its use is not limited by availability, but by demand. It will provide a rising share of energy supplies, both in electric power generation and in industrial applications as a substitute for oil and gas. The projection assumes substantial growth in international coal trade. For example, coal imports into Western Europe, where production will increase only modestly, are projected to account for about 40 percent of Europe's coal in 2000, compared to 15 percent in 1978. The United States is projected to account for almost 50 percent of world coal output by 2000.

Nuclear's share of total energy use is projected to rise to 10 percent by 2000, compared to 3 percent today. In the United States, Europe and Japan, about 85 percent of the 1990 capacity is under construction or in operation, and the balance is on order. Regulatory delays and opposition to the spread of nuclear energy could, of course, lower the projected growth. On the other hand, increased growth in nuclear energy could result from a favorable change in public attitudes or from the use of nuclear capacity for meeting some of the variations in demand above base load requirements (intermediate load following).

Somewhat more than half of the growth of hydropower occurs in Latin America where the availability of sites permits the development of large projects. Hydropower's overall share should increase modestly in the outlook period.

Solar power, included in hydro and other, is projected to contribute about 1 percent of energy supply by 2000. Even this contribution will require a major installation of facilities. In the United States about 5 million homes are projected to have solar hot water systems and about 2½ million to have solar heating systems. About twice this number of installations are projected outside the United States. By 2000, solar power, at the point of energy use, is estimated at around one half million barrels per day oil equivalent. However, in most current



applications solar power replaces electricity. Because this use avoids the energy losses associated with central electric power generation, this half million barrels per day saves the equivalent of about 1½ million barrels per day of energy supply.

It is expected that the cost of energy supplies, adjusted for inflation, will rise in the future since the most accessible and lowest cost energy sources were developed first. A rising proportion of conventional oil and gas supplies may come from basins in frontier areas where oil is more costly than from historical sources such as the Middle East. Synthetic fuels production will become significant in the 1990s as a supplement to conventional oil and gas. These fuels are costly, but production of some becomes economic at projected oil prices and project costs. While technology and experience will provide a partial offset, the trend of energy costs is upward.

A number of possibilities thus exist for increasing the supply of energy. However, lead times required to achieve commercial production are often very long. This is the result of factors such as time to demonstrate new technology, to obtain regulatory permits, to provide for environmental safeguards, to develop infrastructure in remote locations, to construct facilities in harsh physical conditions and to complete commercial arrangements.

Development of all types of energy sources is required to meet the energy demand projected in this Outlook. Substantial shortfalls in any of the sources could not be easily made up by others. If energy sources are not developed at rates near those assumed in this Outlook, economic growth could be lower.

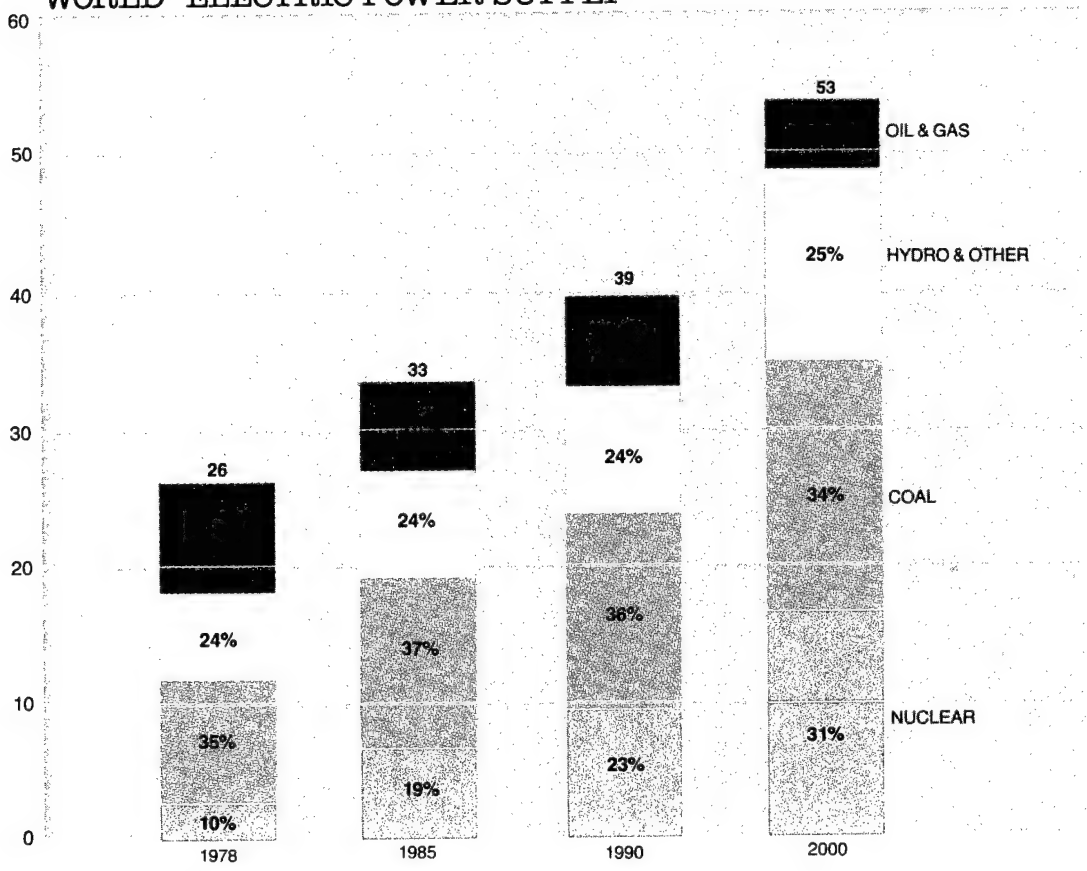
Electricity represents a relatively costly but convenient form of energy, and it can be derived from all primary energy sources. It is the most economical method of using some sources, such as uranium and falling water. The use of electricity in the transportation sector has been limited primarily because it is costly to store. However, other attributes have caused electricity consumption to grow historically at a faster rate than total energy, and it will probably continue to do so. Its growth rate of 3 to 3½ percent per year between now and 2000 is about one-third faster than the total energy growth rate of 2½ percent per year over the same period. This means that primary energy for electric power generation is accounting for an increasing proportion of total energy demand—rising from 29 percent in 1978 to 34 percent in 1990 and to 37 percent by 2000. Because electricity can be made from energy sources in ample supply such as coal, and potentially in the next century from the breeder reactor and fusion power, this trend to a higher dependency on electricity is likely to continue.

The chart illustrates that the transition towards fuels other than oil and gas in the generation of electric power is already under way. Conventional nuclear energy, which is capturing most of the oil and gas share, supplied 10 percent of electric power in 1978. By 2000 it could contribute almost one third. Oil and gas, needed for applications where their unique qualities are best utilized, decline as fuels for electric power in almost a mirror image of the growth in nuclear—that is, from 31 percent in 1978 to 10 percent in 2000. Coal and hydro both are forecast to expand substantially in absolute amount, but to hold constant in share of total.

As noted elsewhere, hydropower is limited by the availability of economic sites, and coal, both by cost compared with nuclear energy and by environmental constraints. Any increased resistance to the development of nuclear energy, however, could lead to higher demand for petroleum in the near term and coal in the long term.

Lead times for the construction of electric power generating facilities are quite long. They range from six to eight years for coal-fired plants and from eight to twelve years for nuclear plants in the United States and Europe. In Japan, a somewhat shorter minimum lead time of about six years is attainable for nuclear facilities.

WORLD* ELECTRIC POWER SUPPLY



MILLION BARRELS/DAY OIL EQUIVALENT
*EXCLUDING AFRICA, MIDDLE EAST, U.S.S.R., EASTERN EUROPE AND THE PEOPLE'S REPUBLIC OF CHINA

Nuclear energy remains one of the faster growing segments of energy supply. As indicated in the table below, capacity is expected to triple between now and 1990, growing about 10 percent per year. A further increase is anticipated during the 1990s of some 250 gigawatts, or 2½ times the total year-end 1978 capacity. Almost three-quarters of the growth in installed capacity during the 1990s is outside the United States, and the number of plants projected to come onstream each year in that decade is not significantly higher than the number planned for the 1980s.

CURRENT OUTLOOK
INSTALLED CAPACITY–GIGAWATTS

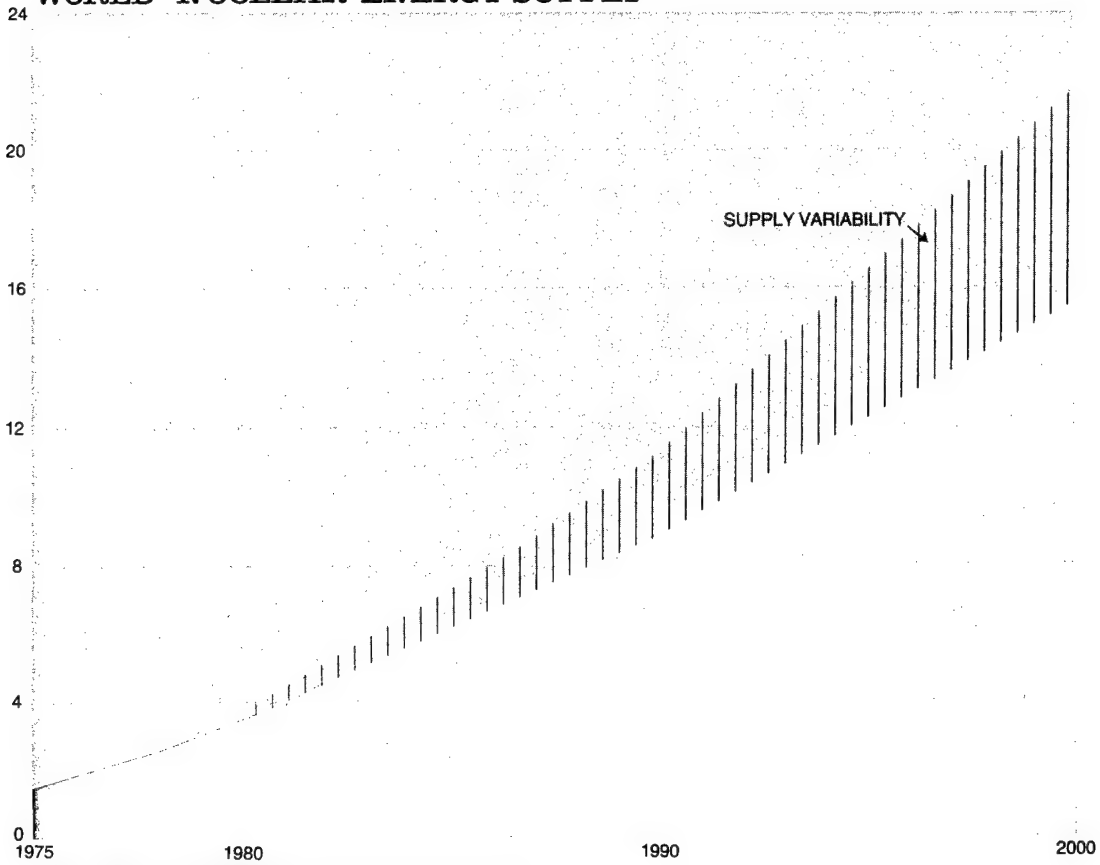
	1978	1990	2000
United States	53	147	207
Europe	30	117	230
Japan	12	39	77
Other	7	46	88
Total	102	349	602

The hatched area on the chart indicates the variability in the current Outlook projection and shows considerable upward potential, especially in the 1990s. Higher supply could occur with a more favorable political attitude toward nuclear energy (noticeable now in countries with few energy supply options such as France and Japan), greater need for electricity and installation of nuclear capacity for "load following"–that is, varying production of electricity more in line with normal fluctuations in demand. Intensified public resistance would have the opposite effect, either by increasing construction lead time or by precluding new plants in certain areas.

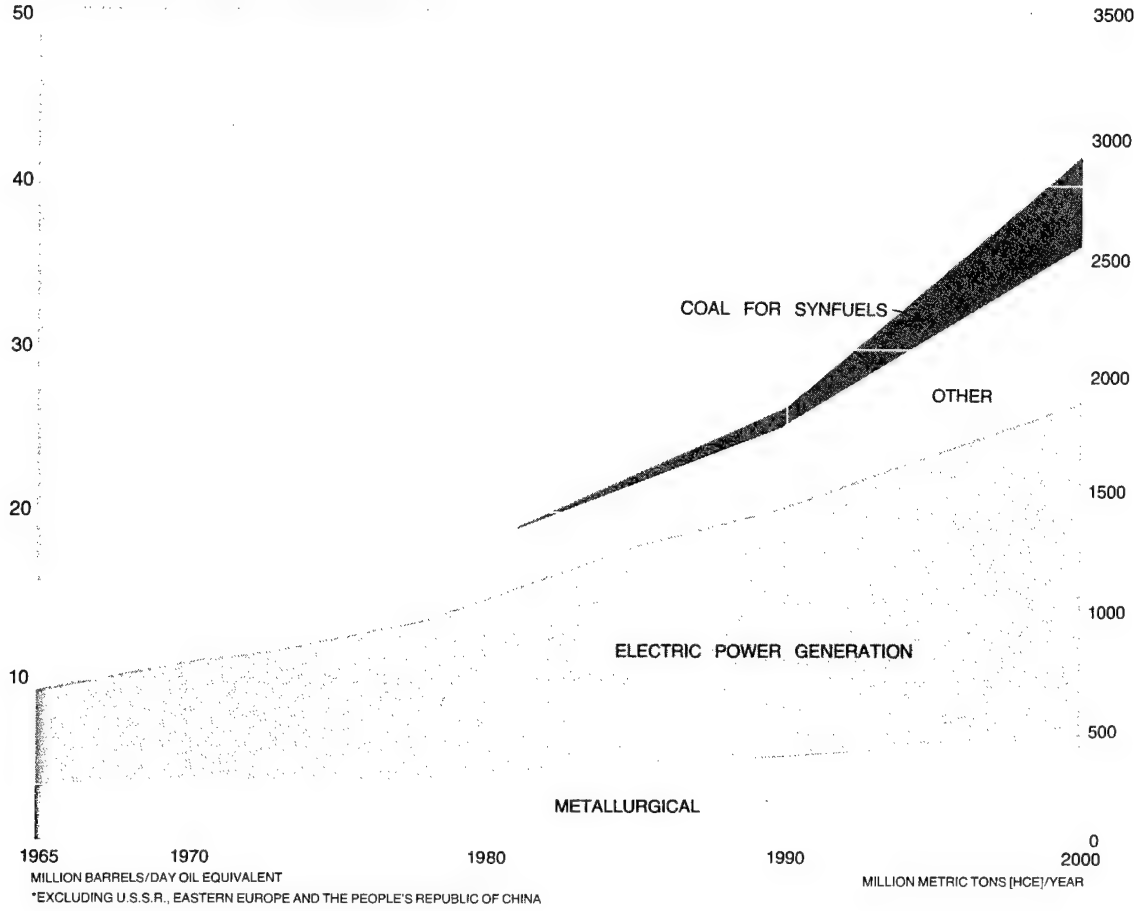
Current and planned capacity for uranium supply and enrichment is adequate through the mid-1990s. Currently almost all nuclear plant fuel is enriched in the United States, but by 1990, 35 to 40 percent will be handled elsewhere.

A number of countries are proceeding with plans for spent fuel reprocessing, although the United States is not. This is a step which will both extend the available uranium supplies and reduce the disposal problem. Because no plans for permanent spent fuel disposal have been completed and reprocessing is not common, utilities now store spent fuel in pools at their reactors. The lack of approved, long-term storage mechanisms can become an increasing problem in expanding reactor capacity. Several countries are working on methods for spent fuel storage and waste disposal, but no plans have been finalized.

WORLD* NUCLEAR ENERGY SUPPLY



WORLD* COAL DEMAND



WORLD COAL OUTLOOK

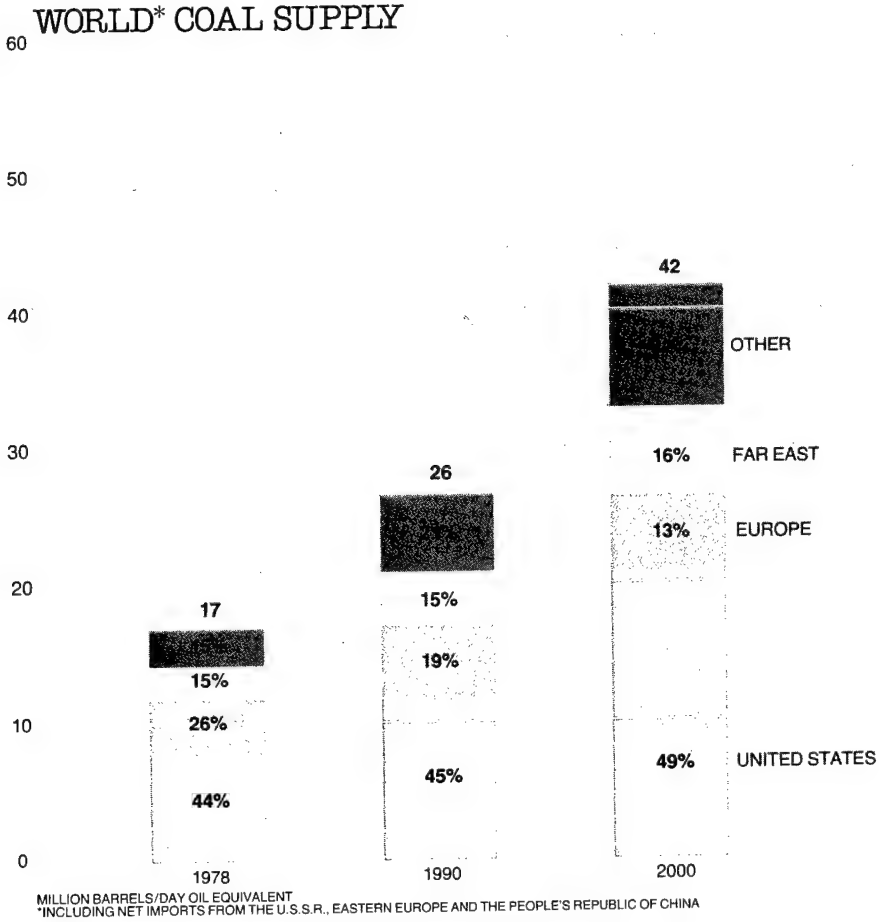
World coal demand is expected to show steady growth through the year 2000 in contrast to the nearly flat demand since 1965, as indicated in the following table.

COAL DEMAND GROWTH, PERCENT PER YEAR

	1965-1978	1978-1990	1990-2000
Metallurgical	0.6	2.8	2.5
Electric Power	4.2	3.7	2.9
Other	(5.1)	5.0	9.7
Total	0.5	3.8	4.8

Metallurgical coal demand is projected to grow at a rate of 2½ to 3 percent per year. Coal demand for electric power generation continues to expand, but at somewhat lower rates than in the last few years because of increasing inroads by nuclear on base-load electric utility requirements and the decline in electric power growth rates. Other thermal uses for coal are expected to reverse their decline and grow at 5 percent per year in the 1980s, reflecting both higher oil prices and laws mandating coal use in large boilers. Beginning in the late 1980s, coal demand for conversion to either synthetic gas or liquids is expected to accelerate. Feed to coal synthetics plants is projected to comprise about 13 percent of coal consumption in 2000, most of it in the United States. The table left includes total coal used in synfuels manufacture (both production and losses) in the Other demand growth rates. For the World Energy Supply table which appears on page 10, the synthetic gas and liquids produced from coal are included as synthetics supply.

WORLD* COAL SUPPLY



The greatest constraints on the use of coal arise from environmental problems and the costs of overcoming them. Some accommodation with environmental concerns, either through technological change or revised regulations, will be required to achieve the demand levels shown on the World Coal Demand chart.

The United States continues as the major producer, and its share of world supply is forecast to increase from 44 percent in 1978 to nearly 50 percent of a much larger total in 2000, as shown in the World Coal Supply chart. Of U.S. coal production, about 5 to 10 percent will be for export markets. Europe's production, equal to 26 percent of the world total in 1978, satisfied 85 percent of local demand in that year. By 2000 Europe's production will meet only about 60 percent of local demand.

Production capacity for export markets will increase in Latin America, Africa, the Far East and the United States, and major increases are anticipated in the amount of coal entering international trade. Expanded transportation facilities will be needed both for growing international movements, particularly to Europe and Japan, and for domestic shipments within the United States. Net volumes of coal imports from Eastern Europe, the U.S.S.R. and the People's Republic of China will probably increase somewhat, but remain less than 3 percent of world demand.

Patterns of natural gas use in the major energy consuming regions of the world have largely reflected the pace at which local supplies have been discovered and developed. Because of the high cost for long distance transportation, including processing where gas has to be liquefied, significant international movements have begun only recently, with a number of additional projects now under development.

U. S. natural gas production peaked in 1973 and has been declining since then. The downward trend is likely to be moderated in the mid-1980s with the completion of the pipeline from Alaska to the lower 48 states. Domestic natural gas supplies have been supplemented by imports, mostly by pipeline from Canada and LNG from Algeria. Imports will increase to 1½ million barrels per day oil equivalent by 1990 and, thereafter, will change little through the 1990s. As early as the mid-1980s synthetic gas supplies may become available, and by 2000 over 15 percent of the gas used in the United States is projected to be supplied by synthetics.

European gas consumption grew rapidly with the discoveries of Dutch reserves in the early 1960s. European supplies are expected to continue to increase until the mid-1980s when continued growth in demand must be met by increases in imports. Algeria is a major supply source, and contracts have been negotiated for supplies through the mid-1980s. By 2000, about half of Europe's supplies will probably be from imports, which will require the development of major facilities.

Japan relies almost entirely on imports for its gas consumption, and these are projected to increase significantly. In addition to sources within the Far East, by 1990 significant volumes are projected to be imported from the Middle East. Increases in gas movements to Japan are dependent on investments in large liquefied natural gas facilities for which plans must be developed.

The largest share of projected growth in world gas consumption is in the developing countries. This growth largely depends on the completion of a number of projects for utilizing local gas production in these countries, especially in the Middle East and Latin America.

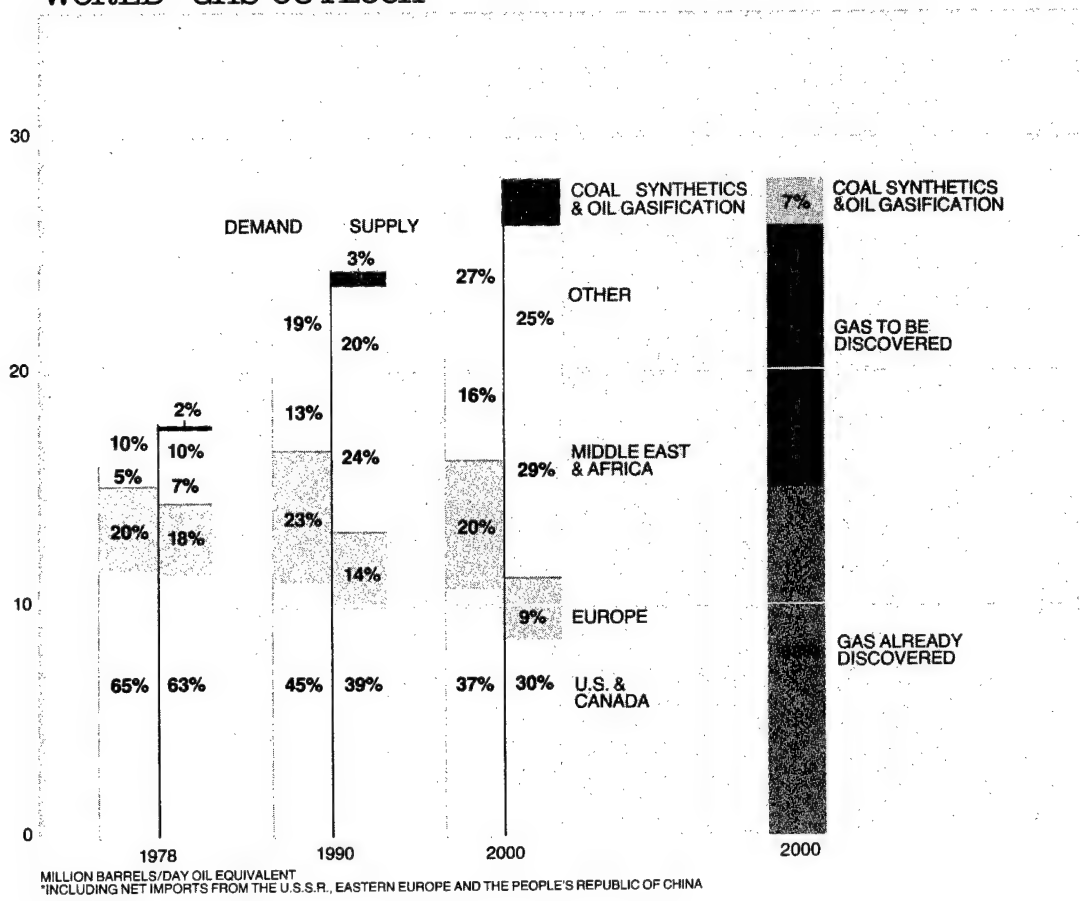
The table below summarizes projected rates of demand growth in major gas consuming areas.

GAS DEMAND GROWTH, PERCENT PER YEAR

	1965-1978	1978-1990	1990-2000
United States	1.9	(0.7)	(0.8)
Europe	19.4	3.8	0.3
Japan	21.8	10.8	5.8
Other	9.2	8.1	3.6
Total	4.7	2.8	1.5

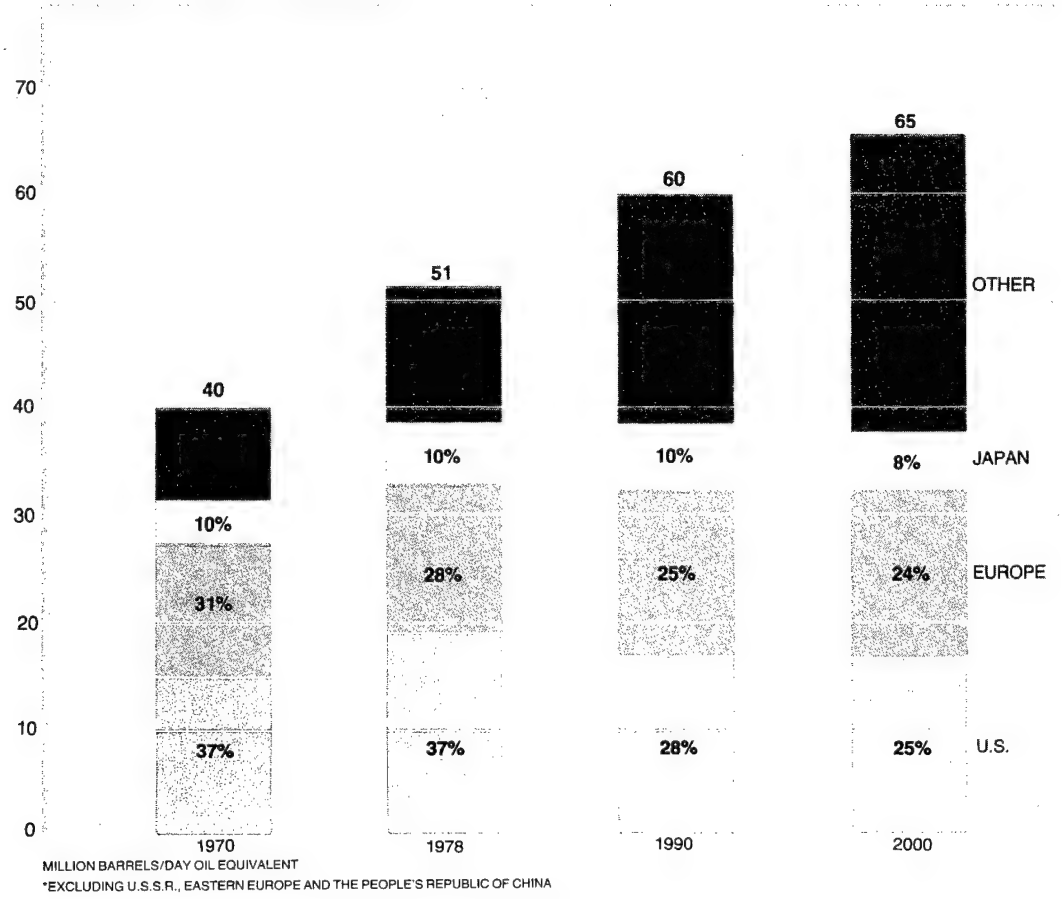
The bar at the right of the chart shows gas supply in 2000 in terms of reserves already discovered and volumes which are expected to come from reserves yet to be discovered and from synthetic production. The synthetic gas volume is virtually all from facilities yet to be built.

WORLD* GAS OUTLOOK



MILLION BARRELS/DAY OIL EQUIVALENT
*INCLUDING NET IMPORTS FROM THE U.S.S.R., EASTERN EUROPE AND THE PEOPLE'S REPUBLIC OF CHINA

WORLD* OIL DEMAND



WORLD OIL OUTLOOK

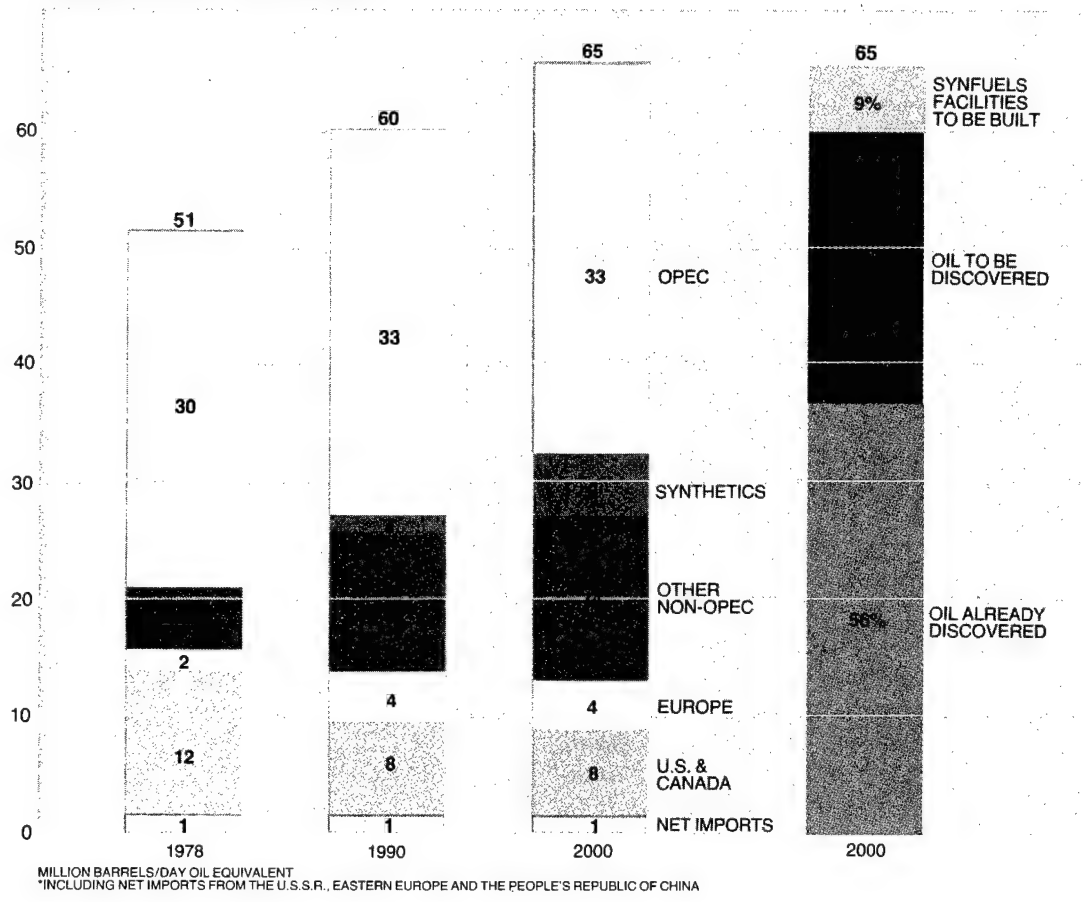
Growth of world oil consumption in the past has been largely in the major industrialized countries. In 1978, almost 75 percent of the world's total oil consumption was in the United States, Europe and Japan. However, as the chart shows, no growth overall is anticipated for these areas in the years ahead with some increases in Europe more than offset by decreases elsewhere, especially in the United States. It is the energy exporting countries and the balance of the developing world which account for the 14 million barrel per day increase in world oil demand during the outlook period.

The percentage numbers in the table at right define the proportion of total oil demand in the United States and Europe which is projected to be satisfied by domestic conventional oil production—that is, total domestic crude oil and natural gas liquids production but not including synthetics. The United States produced 79 percent of the oil it consumed in 1970, but only 58 percent in 1978. By 2000, only about 40 percent is projected to come from conventional production with the balance either imported or derived from synthetics manufacture. For Europe, the share of consumption from domestic conventional production is anticipated to rise to a peak around 1990, as development of North Sea reserves is extended, but a gradual decline is foreseen thereafter as these fields mature.

DOMESTIC CONVENTIONAL OIL PRODUCTION
PERCENT SHARE OF OIL DEMAND

	1970	1978	1990	2000
United States	79	58	40	40
Europe	3	13	28	27

WORLD* OIL SUPPLY



Oil supplies projected on this chart include crude oil production, liquids recovered from natural gas and liquid synthetic fuels.

The ability to produce crude oil is limited by the availability of discovered reserves,[1] reservoir characteristics and the rate at which new reserves are found and developed. It is anticipated that more oil will continue to be produced than discovered, so discovered reserves will continue to decline. There appears to be a growing tendency among governments of some major oil exporting countries to limit current oil-producing rates in anticipation of higher prices. The relatively small current needs of some of these countries for increased revenues and their problems in finding satisfactory investments for excess funds also encourage this tendency.

These projections show net imports from the U.S.S.R., Eastern Europe, and the People's Republic of China continuing in the range of 1 million barrels per day, with declines in availability from the U.S.S.R. offset by gradually increasing amounts from the People's Republic of China.

(continued)

[1] "Discovered" reserves means the total quantity of oil which is expected to eventually be recoverable from already discovered fields. It is the sum of "proved" reserves (the oil estimated to be economically attractive to produce, under current conditions, from those portions of each field where oil content has been confirmed by drilling and testing) plus "probable" reserves (the oil expected to be produced from other portions of the field or as a result of future improvements in recovery efficiency).

Conventional oil production, including natural gas liquids (NGL), from the United States and Canada is expected to continue to decline through the 1980s. The extent of the decline shown on page 21 could be moderated by significantly greater exploration success than projected. However, the deep water or frigid climate in most areas with potential for substantial new discoveries means that production costs will be high. Moreover, output will materialize only years after the exploration effort is first undertaken. Lead times from acquisition of acreage in frontier areas to the start of commercial production range from 6 to 13 years. Continued improvements in enhanced recovery technology are assumed, but as important as these developments would be, they are unlikely to alter the broad trends in the Outlook.

Production increases in Europe will result from continued development of reserves in the North Sea. Future production will be affected by the pace of exploration permitted by the governments of countries which control this acreage, as well as by exploration success and the production policies of these countries.

Production in other non-OPEC countries is anticipated to nearly triple during the outlook period, with Mexican oil likely to be a significant component of this increase.

Worldwide, liquids from synthetics plants begin to appear in appreciable quantities in 1990, rising potentially to around 6 to 8 million barrels per day by 2000.

OPEC production, including NGL, is projected to fall within a 30 to 35 million barrels per day range (28 to 32 for crude oil alone) during the outlook period. Major uncertainties exist concerning OPEC production levels, and even constant crude oil production means a significant decline in exports because of increased oil consumption within the OPEC countries themselves.

The bar at the right of the chart on page 21 shows oil supply in 2000 in terms of existing facilities or known reserves. Roughly 35 percent of the total oil is expected to come from oil reserves yet to be discovered. The synthetic fuels volume is virtually all from plants yet to be built.

RATE OF DISCOVERY OF WORLD OIL RESERVES

Oil is projected to remain the largest single source of supply for meeting world energy demand over the period to 2000. Its availability will necessarily depend on the rate of discovery of new reserves.

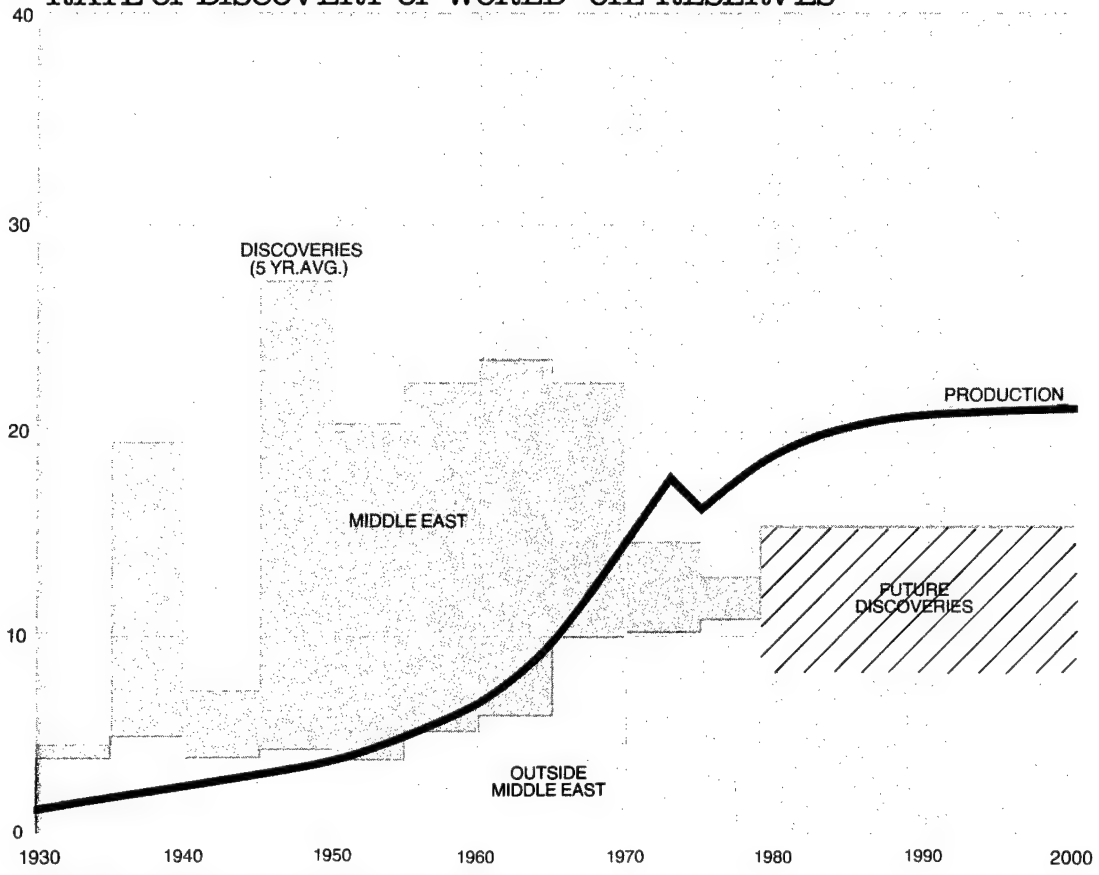
This chart shows that since 1930, oil discovery rates[1] have ranged from less than 10 to more than 25 billion barrels per year. Prior to 1970, discovery rates were well in excess of production, so the world's inventory of discovered reserves was increasing. Since the early 1970s, a decline in oil discoveries and a continuing rise in oil consumption have reversed this situation. As a result, the inventory of discovered reserves has now begun to decline. This pattern is expected to continue, despite a projected growth rate for oil consumption of less than 1 percent per year and assumed aggressive efforts to accelerate discoveries.

The world's remaining conventional oil resources are assessed to be in the range of 1 to 1½ trillion barrels. This number includes oil which has yet to be discovered. Many of the best exploration prospects are situated in remote locations or harsh operating environments as in the Arctic, where finding and developing oil will be difficult and costly. Moreover, in those areas where production already exists, future discoveries are anticipated to be smaller, on average, than past discoveries.

Consequently, even with a very active exploration effort, the average discovery rate for the outlook period is likely to be well below the expected production rate of about 20 billion barrels per year. The unavoidable result will be further decline in the world's inventory of discovered reserves. Production cannot continue growing under these circumstances, and it is reasonable to expect it to plateau around the turn of the century.

[1] The amounts shown are averaged over five-year periods. Each period includes the reserves initially attributed to the fields discovered during that time, plus all revisions which were made in subsequent years.

RATE OF DISCOVERY OF WORLD* OIL RESERVES



BILLION BARRELS/YEAR
*EXCLUDING U.S.S.R., EASTERN EUROPE AND THE PEOPLE'S REPUBLIC OF CHINA

Synthetic fuels are liquids and gases readily substituted for conventional oil products and natural gas in most applications. They can be derived from coal, heavy oil, oil sands, oil shale and from agricultural products. Since fossil fuel synthetics production can draw from a resource base several fold that for conventional oil, the reserves are not presently a limiting factor. These resources can make a meaningful contribution to energy supplies as conventional oil and natural gas become more costly and difficult to secure. Although subject to many uncertainties, oil and gas synthetics could provide about 2 million barrels per day oil equivalent by 1990 and 7 to 9 million barrels per day by 2000. The chart shows one reasonable projection for synthetic fuels production in the outlook period. The table shows the share of oil and gas demand which is projected to be met from synfuels production, based on the lower end of the range.

SYNTHETICS AS PERCENT OF OIL AND GAS DEMAND

	1990	2000
United States	3	16
Canada	15	30
Venezuela	21	41
Brazil	12	18
Others	*	2
World	2	8

*Less than .5%

Volumes in the United States include significant contributions from shale oil and both gas and liquids from coal. Supplies in Venezuela and Canada are liquids from heavy oil and oil sands recovery. Brazil's near-term synthetics are mostly alcohol from agricultural products with growth potential also in shale oil and coal. Elsewhere, the volume is about equally divided between shale oil and coal gas and liquids.

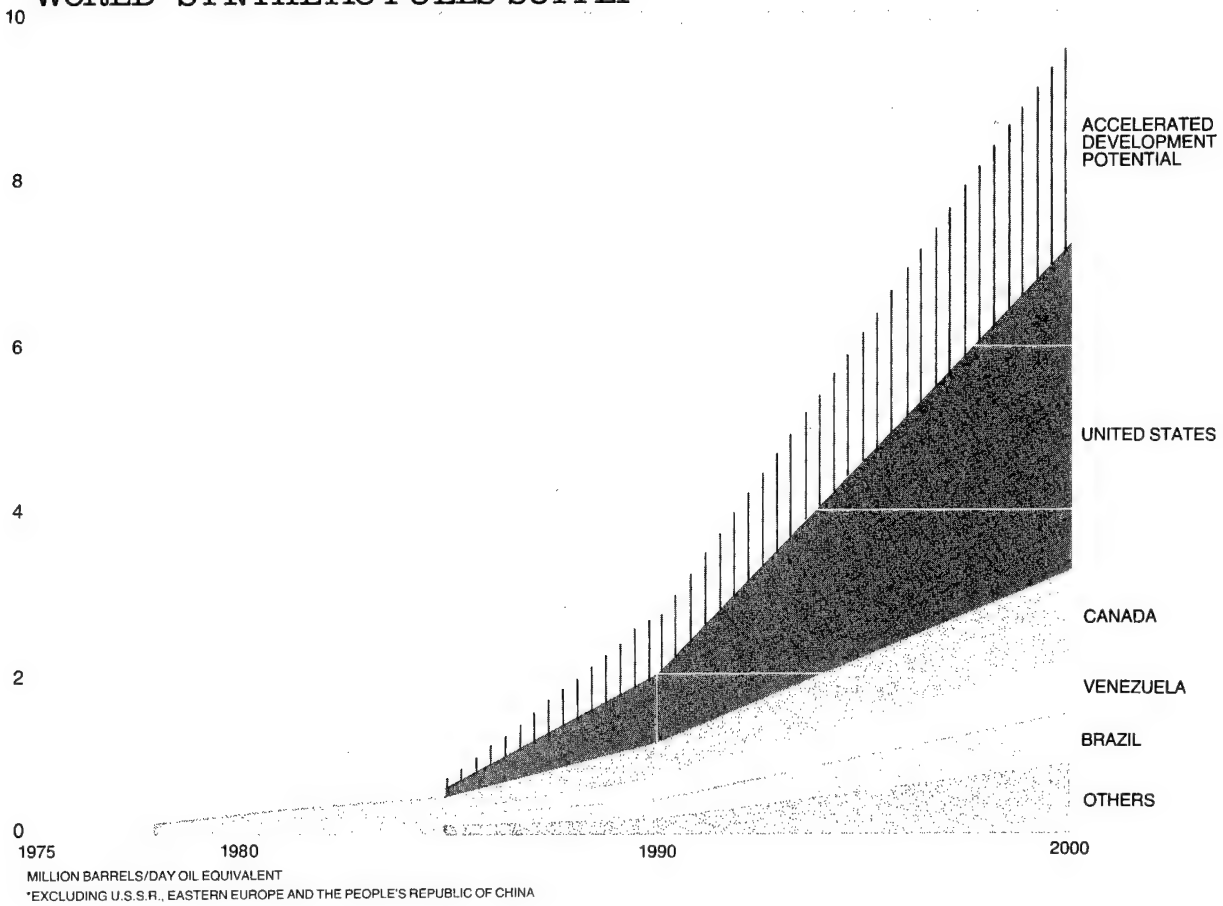
While significant commercial volumes appear technologically feasible by the 1990s, their attainment requires overcoming important obstacles. Lead times for synthetics are substantial—about seven to ten years. Most processes are very costly and few have been demonstrated in plants of commercial size. If the projections made here for the 1990s are to materialize, industry and governments have to make and implement decisions soon about the development sequence from research to manufacturing.

Because of its substantial coal and oil shale reserves, as well as its financial and technological capabilities, the United States has the greatest potential for the development of major volumes of synthetic fuels over the next 20 years. By 1990 U. S. synfuels production could be about three-quarters to 1½ million barrels per day oil equivalent, and it could reach 4 to 6 million barrels per day by 2000. Canada and Venezuela have substantial potential, and Canada has already begun production. Other areas of the world also have potential for producing synthetic fuels.

The hatched area on the chart suggests the potential for accelerated synfuels development which would be largely in the United States. This higher level of production, some additional 2 million barrels per day which could bring total U. S. synfuels production to 6 million barrels per day by 2000, would require a commitment to a more accelerated program than already assumed in the Outlook. Government policies, especially those related to environmental protection and access to resources, will have a significant influence on the rates at which synthetics can be developed in the United States and elsewhere.

Where resources are available, aggressive programs for synthetics manufacture can significantly reduce the requirement for imported oil. The table indicates that synthetics could amount to a substantial portion of total oil and gas demand in a number of countries. To the extent that synthetics production does not materialize as projected, these countries may need to expand oil imports above projected levels, putting further pressure on limited world conventional oil and gas supplies. Alternatively, the economic growth rate may be lower because of reduced availability of energy supply. In this Outlook, net oil imports into the United States would be about 7 million barrels per day in 2000 with U. S. synthetics production at about 4 million barrels per day. Were synthetics production to be more rapidly developed to reach 6 million barrels per day by 2000, oil imports could be reduced accordingly.

WORLD* SYNTHETIC FUELS SUPPLY



MILLION BARRELS/DAY OIL EQUIVALENT

*EXCLUDING U.S.S.R., EASTERN EUROPE AND THE PEOPLE'S REPUBLIC OF CHINA

Energy demand in the United States is projected to grow at a rate of a little less than 1 percent per year through 1990 with an indicated rise to 1.6 percent per year in the 1990s. However, this latter rate includes the significant effect of a rapid acceleration in synthetic fuels manufacture. Excluding the energy consumed in synfuels manufacture, the growth rate would be 1.2 percent per year, 1990 to 2000. These energy demand increases are associated with projected economic growth rates of about 2½ to 3 percent per year and reflect substantial decreases in the amount of energy required per unit of economic output compared with pre-1970 patterns.

By 1978, the amount of energy required per unit of GNP was lower than the pre-1970 average by about 6 percent, with the reduction about equally divided among the three sectors of industry, transportation and residential/commercial. By 1990 and 2000, energy consumption per unit of GNP is projected to be, respectively, about 22 percent and 30 percent below the levels that would have resulted with the same economic growth if pre-1970 energy/GNP use patterns were to prevail. A growing contribution to this reduction is the assumed continuing efficiency improvement in the automobile and light truck sector throughout the Outlook period. By 2000, the transportation sector is forecast to contribute nearly half of the total savings. Other savings come from such factors as adjusted thermostat settings, more insulation and more energy-efficient home appliances and industrial equipment.

Nuclear energy growth continues to be forecast at relatively high rates, 9 percent per year to 1990 and 4½ percent per year 1990 to 2000. All reactors included in the 1990 total which are not yet built are either on order or under construction. However, new orders will be needed to provide the capacity forecast for 2000. Greater penetration of nuclear beyond the level projected here would require that nuclear capacity be used for "load following".

Hydropower along with geothermal contributed about 1.5 million barrels per day oil equivalent in 1978 and is projected to grow to 2.3 million barrels per day oil equivalent by 2000. While a large number of sites have the potential for low-head hydropower development, the maximum contribution from this energy source is about one half million barrels per day oil equivalent. Alcohol from biomass is not projected to exceed 100 thousand barrels per day by 2000. Solar energy, on a delivered basis, is estimated at about 200 thousand barrels per day oil equivalent, but this could vary considerably.

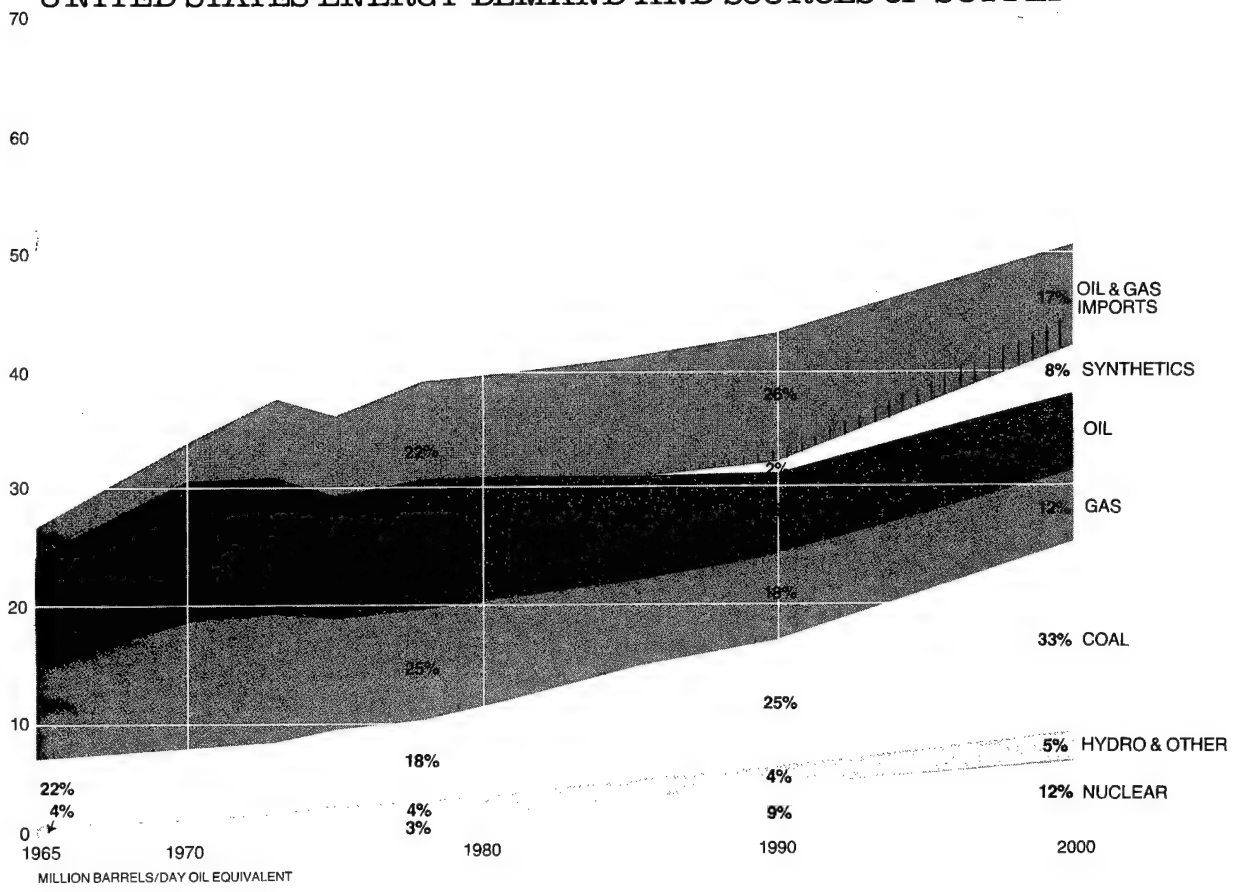
Coal is projected to be the largest contributor to energy growth with total production increasing from 7.4 million barrels per day oil equivalent in 1978 to over 20 million barrels per day oil equivalent by 2000. Of this total, about 1.5 million barrels per day oil equivalent are projected to be exported and 2.5 million barrels per day oil equivalent will be available in the form of liquids and gas from synthetics plants. (The coal input to synfuels plants will be nearly 5 million barrels per day oil equivalent.) Coal consumption excluding that related to synfuels production (output and losses) is projected to rise from about 600 million short tons in 1978 to 1 billion tons in 1990 and 1½ billion tons in 2000.

Natural gas production is projected to decline over the outlook period, with the easing of this trend in the mid-1980s when supplies from the North Slope of Alaska are forecast to become available upon completion of a pipeline to the lower 48 states.

Domestic oil production is projected to gradually decline from its current level of 10.3 million barrels per day, including natural gas liquids, to between 6 and 6½ million barrels per day in the 1990s. This projection could be subject to some variation due to the rate at which federal lands and offshore areas are made available for exploration, the success of exploration, the time needed for development and the results longer term of further efforts at enhanced oil recovery.

Synthetics manufacture, both from coal and shale oil, is subject to considerable variation and production levels will have a direct bearing on the level of U.S. energy imports. Key factors affecting the rate of development of synfuels

UNITED STATES ENERGY DEMAND AND SOURCES OF SUPPLY



production include the extent of support provided by federal and local governments, and the perception of competing energy prices by potential investors. Production could range from three-quarters to 1½ million barrels per day oil equivalent by 1990 and from 4 to 6 million barrels per day by 2000.

Oil and gas imports are projected to be within a 9 to 11 million barrels per day oil equivalent range throughout most of the 1980s and then decline during the 1990s, assuming the availability of supplies of synthetics from coal and oil shale. This Outlook was prepared without assuming a policy limit on U.S. oil imports.

While imports of about 9 million barrels per day of oil plus gas would be required in 2000 with a synfuels production level of 4 million barrels per day, they could decline to 7 million barrels per day with 6 million barrels per day of synfuels as illustrated by the hatched area. Gas imports included in the figures above are projected to increase from the current .6 million barrels per day oil equivalent level to about 1.5 million barrels per day oil equivalent in the 1990s. This increase includes added volumes of liquefied natural gas from the Far East and Africa, but the primary source is overland supplies from Canada.

The table below summarizes the growth rate projections for U. S. energy demand and supply.

AVERAGE GROWTH, PERCENT PER YEAR

	1965-1973	1973-1978	1978-1990	1990-2000
Energy Demand	4.3	1.0	0.8	1.6
Domestic Supply	3.1	(0.3)	0.4	2.9
Imports	12.7	5.4	2.4	(2.6)

The economic growth projection of 2½ to 3 percent per year is lower than the 1965 to 1973 rate of 4½ percent per year. Energy demand in Europe is projected to grow at about 2 percent per year through 2000, down from a 5 percent annual growth rate in the decade prior to 1973. Reduced energy intensity in Europe results in a 12 percent reduction in energy requirements in 1990 compared to the volumes that would have been needed if the pre-1970 average energy/GNP ratio had continued. In 2000, the savings are expected to rise to 18 percent. These reductions in energy demand will be due to improvements in conservation, efficiency and changes in the economic mix, and they will occur principally in the industrial and residential/commercial sectors.

AVERAGE GROWTH, PERCENT PER YEAR

	1965-1973	1973-1978	1978-1990	1990-2000
Energy Demand	5.1	1.0	2.0	1.7
Domestic Supply	1.0	5.2	3.5	1.6
Imports	9.1	(2.7)	0.7	1.8

As the table above indicates, domestic energy supply is anticipated to increase at about 3½ percent per year to 1990 compared with the 2 percent annual growth in demand, and then to grow at about the same rate as demand in the 1990s. While energy imports will therefore decline as a percent of total requirements—from 53 percent in 1978 to 46 percent by 2000—they will nevertheless increase in volume by 30 percent in this period. These trends are illustrated graphically in the chart.

The energy supply projected to grow most rapidly overall is nuclear, increasing from 3 percent in 1978 to 16 percent of the total by 2000. France will experience the largest nuclear growth followed by West Germany. The United Kingdom and Italy are next but, combined, they do not equal the projected growth in either of the first two.

Local coal production is forecast to rise somewhat over the next 20 years, mainly in West Germany and the United Kingdom. Gas production is expected to peak in the mid-1980s, and by 2000 to be somewhat below current levels.

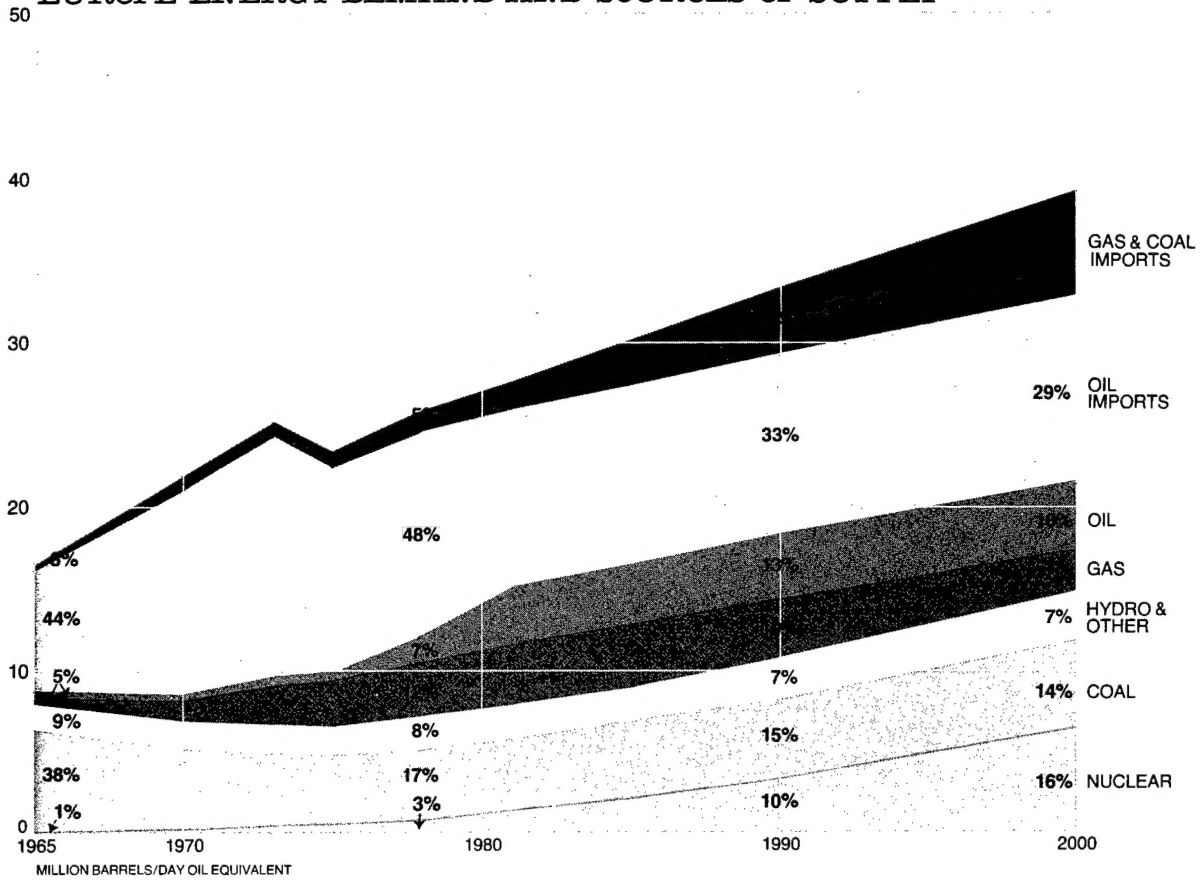
Oil production will continue to expand through the mid-1980s, and stabilize thereafter. Longer term production rates will be dependent both on exploration success, particularly in the North Sea sectors of the United Kingdom and Norway, and on the production policies set by these nations.

As a result of low oil demand growth and rising domestic production, oil imports are expected to decline and then remain essentially constant. However, by 2000 they will still represent nearly 30 percent of energy requirements.

Natural gas imports are forecast to rise to between 2.5 and 3 million barrels per day oil equivalent by 2000 from only .5 million barrels per day currently. Most of the increase will come from Algeria, with some from the U.S.S.R. as well. Much of this volume is yet to be contracted for and substantial investments in facilities will be required for its importation.

Coal imports are expected to show a large increase, rising by about 200 million metric tons of hard coal equivalent which represents nearly 3 million barrels per day oil equivalent. These imports will come from Latin America, the United States and Eastern Hemisphere sources, including theU.S.S.R., Eastern Europe and the People's Republic of China.

EUROPE ENERGY DEMAND AND SOURCES OF SUPPLY



The Japanese economy continues to show a significant reduction in growth in energy demand, with an average increase of 2½ percent per year projected to 2000 compared to an 11 percent growth rate in the period prior to 1973. This increase in demand is seen as supporting an economic growth rate of 3½ to 4 percent per year, down from the 1965 to 1973 average of 10¾ percent. These projections indicate a substantial lowering in the amount of energy consumed per unit of economic output. Compared with the average of the 1960s, this improving trend reduces energy demand by about 20 percent in 1990, and by about 30 percent in 2000, in contrast to what would have resulted had pre-1970 energy consumption patterns continued. Most of the reductions are due to changes in the industrial area, including the diminishing importance of such sectors as steel and shipbuilding, as well as conservation and increased efficiency in the use of energy.

As the chart shows, Japan remains a nation with very small domestic sources of energy supply. Only if nuclear energy is included in this category do total domestic supplies rise to about 24 percent of demand in 2000 from 12 percent currently. Nuclear power generation is expected to increase from about .2 million barrels per day oil equivalent in 1978 to 1.9 million barrels per day by 2000. At that level, it will provide 15 percent of energy supply. Other domestic energy sources include hydropower and small amounts of fossil fuels.

While dependence on energy imports continues, a shift is projected to take place as oil imports decline slightly and coal and natural gas grow sharply. Gas imports are projected to increase eightfold between 1978 and 2000. Gas imports in 2000 are projected at about 2½ million barrels per day oil equivalent, or half the level of oil imports.

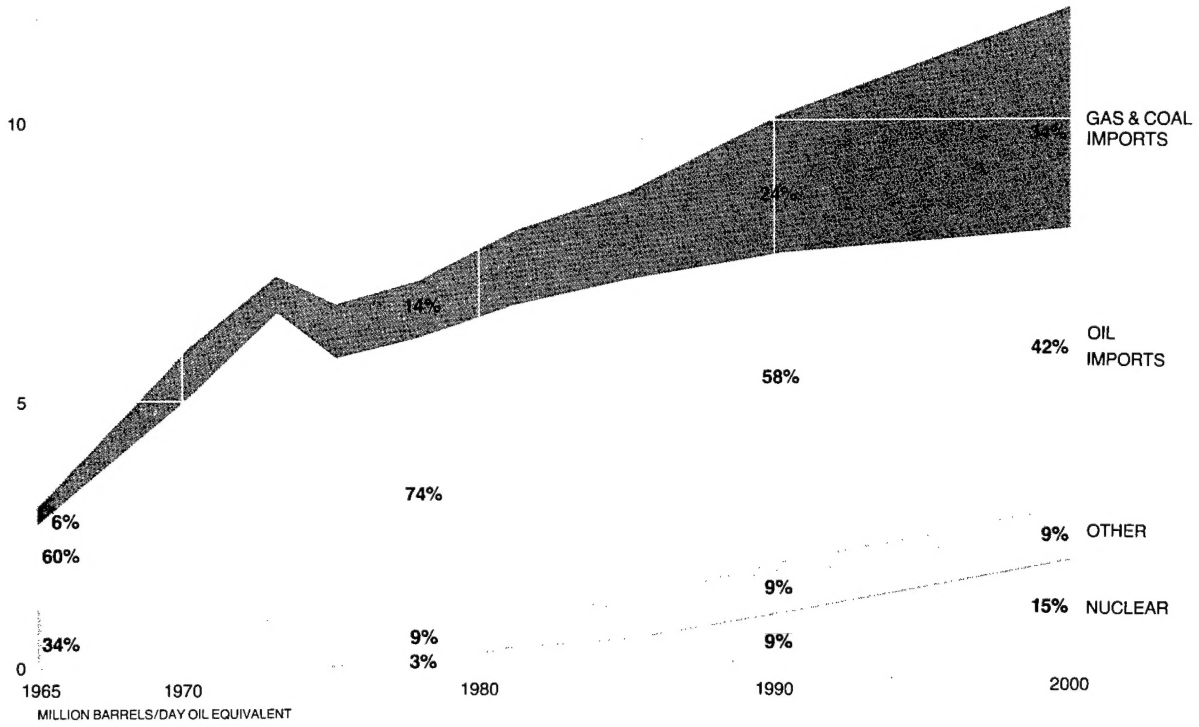
Coal imports are expected to increase to 1.8 million barrels per day oil equivalent by the turn of the century, from .7 million barrels per day oil equivalent in 1978. Historically, most of Japan's coal imports have been used for steel manufacture while much of the growth in the future will be for power plant fuel.

Projected growth rates for energy demand and imports are shown in the table below.

AVERAGE GROWTH RATE PERCENT PER YEAR

	1965-1973	1973-1978	1978-1990	1990-2000
Energy Demand	11.4	0.8	2.9	1.9
Imports	16.5	(0.8)	2.4	1.1

JAPAN ENERGY DEMAND AND SOURCES OF SUPPLY



Despite economic growth rates lower than in the past and despite declining energy/GNP ratios, demand for energy will continue to increase. By 2000, world energy demand could be about two-thirds higher than at present.

Oil consumption will probably continue to exceed discoveries over the next 20 years. Conventional oil production can be expected to plateau around the turn of the century, and costs of new oil supplies will be higher, even after allowing for inflation. Other expensive energy sources will be required to meet projected world energy demand, reinforcing the rise in real energy costs.

The transition to a new energy supply environment will accelerate over the next two decades. Coal and nuclear will play increasingly important roles, and synthetics will become significant in the years beyond 1990. In all sectors of the economy greater conservation and greater efficiency in the use of energy can be expected.

This transition can be achieved. Some of the required technology is available now and new processes are under active development. Development of energy sources in a timely fashion will satisfy the requirements for expanding energy supplies without seriously impinging on economic growth. Access to the required resources, support for the accelerated development of synthetic fuels, and government policies, especially those concerned with environmental controls, will all affect the pace of the transition and its economic and social consequences.

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